N70-38200

May 5, 1964 R. R. FORD 3,132,342

ANTENNA SYSTEM USING PARASITIC ELEMENTS AND TWO DRIVEN ELEMENTS AT 90° ANGLE FED 180° OUT OF PHASE

Filed July 12, 1962 2 Sheets-Sheet 1

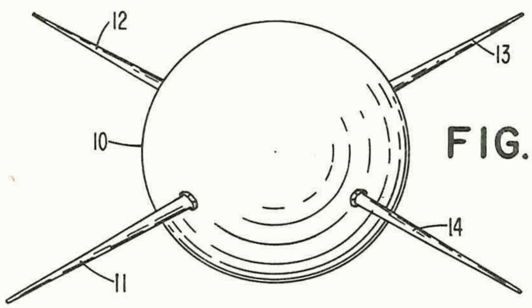

FIG. 1

PRIOR ART

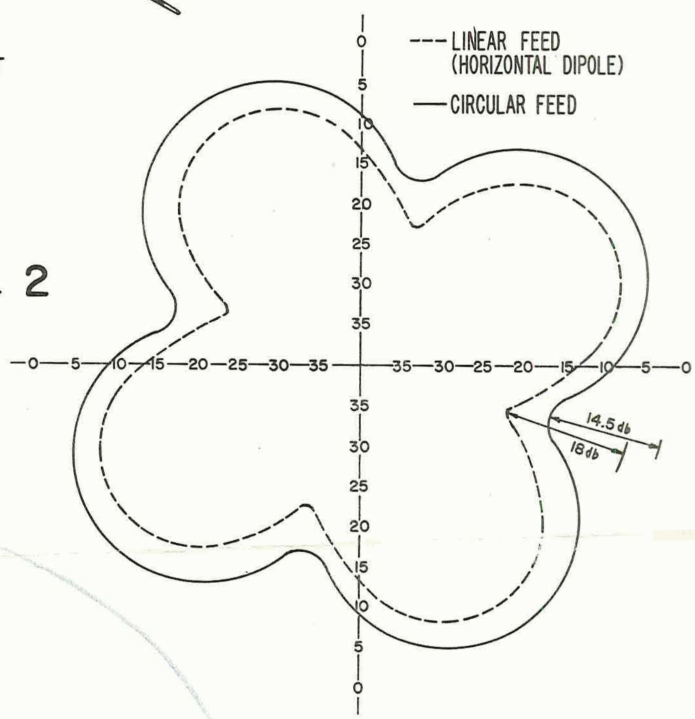

FIG. 2

PRIOR ART

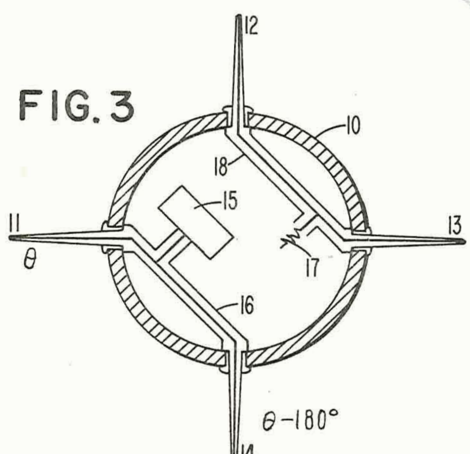

FIG. 3

N70-38200 75%

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ANTENNA SYSTEM USING PARASITIC ELEMENTS AND TWO DRIVEN ELEMENTS AT 90° ANGLE FED 180° OUT OF PHASE

Filed July 12, 1962 2 Sheets-Sheet 2

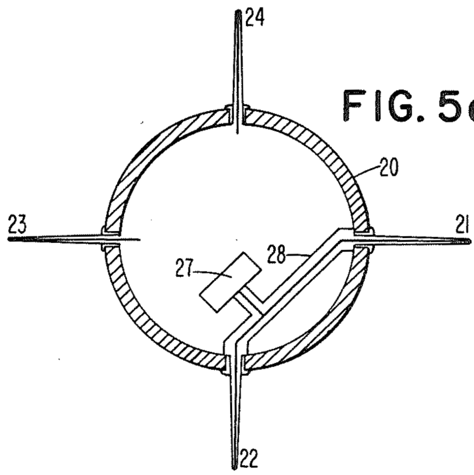

FIG. 5a

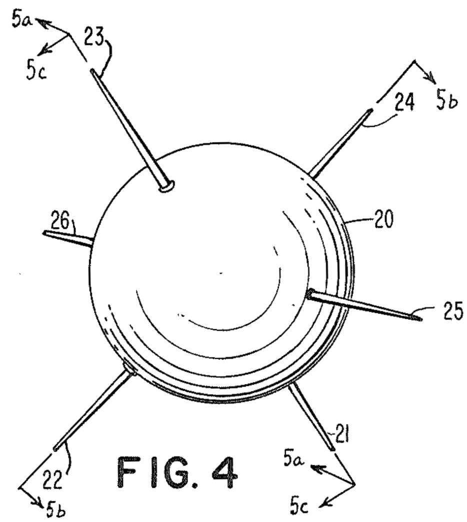

FIG. 4

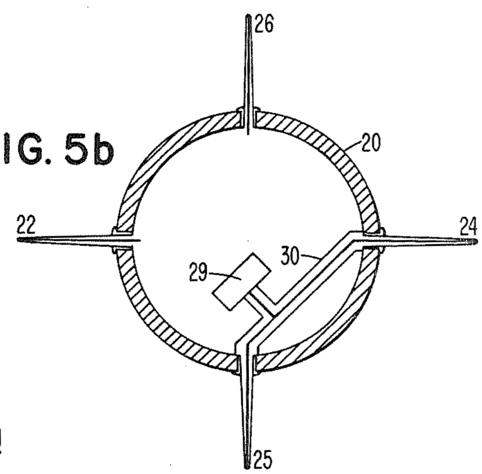

FIG. 5b

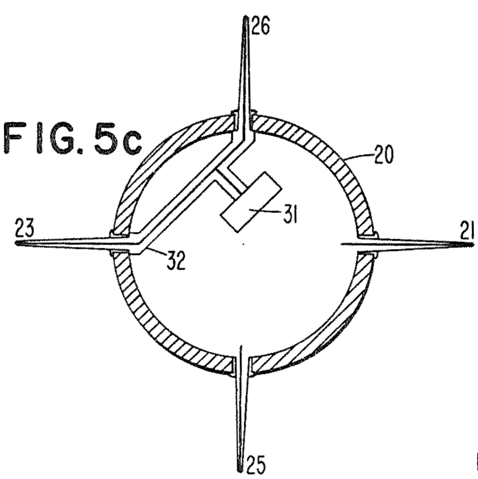

FIG. 5c

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ANTENNA SYSTEM USING PARASITIC ELEMENTS AND TWO DRIVEN ELEMENTS AT 90° ANGLE FED 180° OUT OF PHASE

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7 Claims. (Cl. 343—705)
(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates generally to improved antenna systems, and more particularly to antenna systems with improved omnidirectional radiation characteristics for use on satellites.

A problem usually encountered with a satellite communication system is the orientation of the satellite antenna system with respect to the antenna system of the ground station. This problem arises because antennas generally have directional radiation characteristics and because the orientation of the satellite with respect to Earth is either unknown or continuously changing.

A partial solution to this problem has been the use of monopole antenna elements attached to the outer surface of the satellite. FIG. 1 shows an antenna system which has been used on previously launched satellites. It consists of four monopole antenna elements insulatedly attached in a common plane to the outer surface of the metallic satellite. The four monopole antenna elements are spaced 90° apart physically, and fed in phase quadrature electrically. The radiation pattern of this antenna system has four lobes with appreciable nulls in the plane of the four monopole antenna elements. In future satellite applications, it is important that these nulls be reduced as much as possible.

The general purpose of the present invention is to provide an antenna system for general use and for use on satellites, which embraces all the advantages of similarly employed antennas and which has lesser antenna pattern nulls than previously used antenna systems. In a preferred embodiment of the invention, four monopole elements, each of which is approximately one-quarter wavelength of the transmitting frequency in physical length, are insulatedly attached to the outer surface of a metallic satellite. The four monopole elements are located in a common plane and are spaced 90° apart physically. Two adjacent monopole elements are active elements which are fed 180° out of phase electrically. The remaining two monopole elements are parasitic elements which are interconnected to a load impedance for single frequency operation. Dual frequency operation may be achieved by replacing the load impedance with either a transmitter or receiver operating at a second frequency. In this case, each fed or active pair of monopole elements will use the other pair of monopole elements as parasitic elements.

In another embodiment of the invention, six monopole elements are insulatedly attached to the outer surface of a metallic satellite: four are located in a common plane (on the equator of the satellite) and spaced 90° apart physically, and the other two are located at the two poles of the satellite. The six monopole elements are fed in pairs which allows transmission or reception at three different frequencies. The two monopole elements of each pair are adjacent to each other and are fed 180° out of phase. At each frequency, two monopole elements are fed, and the other four monopole elements are parasitic elements.

The invention is the result of investigations performed with a view to providing an optimum antenna system for the NASA Atmospheric Structure Satellite (S–6). The satellite is a pressurized 35-inch sphere of stainless steel, which has a spinning motion in orbit; its tracking frequency is 136 mc. linearly polarized, and its telemetry and command frequencies are respectively 136 and 120 mc. cross-linearly polarized. The antenna investigations were conducted on a scaled down model (6.5 inches in diameter, or about 1:5.3) of the satellite, with a proportionately increased frequency of 720 mc.

An investigation was conducted on an antenna system mounted on a metallic satellite like the one shown in FIG. 1. The four quarter wavelength monopole elements were mounted on the equator (a circumference) of the model. The four monopole elements were spaced 90° apart physically, and phased 90° apart electrically. Equatorial plane patterns were measured at 720 mc. for both linear feed (horizontal dipole) and circular feed. Linear feed and circular feed mean that the monopole elements are fed so that the electromagnetic waves emitted by them are linearly polarized and circularly polarized, respectively. These patterns are shown in FIG. 2. The dashed line pattern was measured with linear feed. The maximum null depth of this pattern, compared to the maximum pattern lobe, was 18 db. The solid line pattern was measured with a circular feed source, and showed a maximum null depth of 14.5 db.

Another investigation was conducted on an antenna system mounted on the model simulating a metallic satellite. In this investigation four quarter wavelength monopole elements were mounted on the equator of the model and spaced 90° apart physically. Two adjacent monopole elements were fed 180° out of phase with a 720 mc. source. The other two monopole elements were connected to a 50-ohm floating load resistor. Equatorial plane patterns were measured for both linear and circular feeds. The maximum null depth for the linear feed was 6 db and the maximum null depth for the circular feed was 6.3 db. A polar plane pattern was measured for a circular feed and was found to have only a 4 db null depth. This pattern was confirmed by recording a horizontal dipole pattern and a vertical dipole pattern. The vector sum of the horizontal and vertical components gave a pattern with less than 3 db. nulls, when compared to the isotropic radiator reference level.

The results of these investigations conclusively show that monopole antenna elements mounted on a metallic satellite afford better omnidirectional antenna coverage if a number of the monopole elements are connected as parasitic elements.

An object of the invention is to utilize parasitic antenna elements to improve the omnidirectional coverage of an antenna system.

A further object of the invention is to provide a multi-frequency antenna system.

A still further object of the invention is to improve the omnidirectional coverage of an antenna system for satellite application.

Other objects and a fuller understanding of the invention may be had by referring to the following description and claims, taken in conjunction with the accompanying drawings, in which:

FIG. 1 shows a prior art antenna mounted on a metallic satellite, in which one embodiment of this invention is incorporated;

FIG. 2 shows equatorial plane antenna patterns for a prior art antenna system incorporated in the prior art antenna shown in FIG. 1;

FIG. 3 is a cross-sectional view of FIG. 1 incorporating one embodiment of this invention;

FIG. 4 shows six monopole antenna elements insulatedly attached ot the metallic outer surface of a satellite in

which another embodiment of this invention is incorporated; and

FIGS. 5a, 5b, and 5c shows three mutually perpendicular cross-sectional views of FIG. 4 as indicated by section lines 5a—5a—, 5b—5b, and 5c—5c.

With reference to FIG. 3 of the drawings, one embodiment of the invention is illustrated as being incorporated in a metallic spherical satellite indicated generally by the reference character **10**. FIG. 3 is a cross-sectional view of FIG. 1 through the plane containing the four monopole antenna elements **11**, **12**, **13** and **14**. As illustrated, the four monopole antenna elements are insulatedly attached, in the same plane 90° apart, to the outer surface of the satellite; and they are each one quarter of a wavelength of the operating frequency of a transmitter **15** in physical length. Monopole antenna elements **11** and **14** are fed by transmitter **15** through a coaxial cable **16**. The outer conductor of cable **16** is connected to the metallic shell of satellite **10** and the inner conductor of cable **16** is connected to antenna elements **11** and **14**. Transmitter **15** feeds cable **16** at a point one quarter of a wavelength from antenna element **11** and three quarters of a wavelength from antenna element **14**. Consequently, the signals fed to antenna elements **11** and **14** are 180° out of phase. That is, if antenna element **11** is fed at some phase angle θ then antenna element **14** is fed at a phase angle of $\theta-180°$.

Antenna elements **12** and **13** are connected to a floating resistor **17** through a coaxial cable **18**. The outer conductor of cable **18** is connected to the shell of satellite **10**, and the inner conductor of cable **18** is connected to antenna elements **12** and **13**. Resistor **17** is connected to cable **18** at a point three quarters of a wavelength from antenna element **12**, and one quarter of a wavelength from antenna element **13**. The lengths of cable **18** from antenna elements **12** and **13** to the point where the connection is made to resistor **17** are not critical and can be different than shown. For instance, the length of cable **18** from antenna element **12** to the connection can be one half of a wavelength, and the length of the cable **18** from antenna element **13** to the connection can also be one half of a wavelength. It is only necessary that the differences of the two distances be zero or some multiple of one half of a wavelength. The floating resistor **17** is connected to cable **18** to simulate equipment (transmitter or receiver) which might be connected to the antenna elements. The value of resistor **17** is not critical.

In the operation of the embodiment of the invention shown in FIG. 3, signals applied to cable **16** by transmitter **15** are applied to antenna elements **11** and **14**. Because of the relative lengths of cable **16** from transmitter **15** to antenna elements **11** and **14**, the signals applied to antenna elements **11** and **14** are 180° out of phase. Antenna elements **12** and **13** are parasitic and improve the omnidirectional coverage of antenna elements **11** and **14**.

It should be noted that dual frequency operation may be realized by the embodiment of this invention shown by FIG. 3, if the resistor **17** is replaced by a transmitter or receiver operating at a second frequency. If this be true, each pair of monopole elements will be fed or active at one frequency and will be parasitic at the other frequency. For this dual frequency operation monopole elements **12** and **13** should be one quarter of a wavelength of the second frequency, in length, and monopole elements **11** and **14** should be one quarter of a wavelength of the operating frequency of transmitter **15**, in length.

With reference to FIGS. 4 and 5 of the drawings, another embodiment of the invention is illustrated wherein the spherical satellite is indicated generally by the reference character **20**. FIG. 4 shows the metallic spherical satellite **20** with six monopole elements **21**—**26** attached to the surface of the satellite and electrically insulated from the satellite with a suitable insulating material. FIG. 5 shows three mutually perpendicular cross-sectional views of FIG. 4; FIG. 5a is a cross-sectional view of the plane containing monopole antenna elements **21**, **22**, **23** and **24**; FIG. 5b is a cross-sectional view of the plane containing monopole antenna elements **22**, **24**, **25** and **26**; and FIG. 5c is a cross-sectional view of the plane containing monopole antenna elements **21**, **23**, **25** and **26**.

As illustrated in FIG. 5a, four monopole antenna elements (**21**, **22**, **23** and **24**) are insulatedly attached, in the same plane 90° apart, to the outer surface of satellite **20**. Monopole antenna elements **21** and **22** are fed by a transmitter **27** through a coaxial cable **28**. The outer conductor of cable **28** is connected to the metallic shell of satellite **20** and the inner conductor of cable **28** is connected to antenna elements **21** and **22**. The transmitter **27** feeds cable **28** at a point one quarter of a wavelength of the transmitter operating frequency from antenna **22** and three quarters of a wavelength of this operating frequency from antenna **21**. Antenna elements **21** and **22** each have a physical length equal to one quarter of a wavelength of the operating frequency of transmitter **27**.

As illustrated in FIG. 5b, four monopole antenna elements (**24**, **25**, **22** and **26**) are insulatedly attached, in the same plane 90° apart, to the outer surface of satellite **20**. Monopole antenna elements **24** and **25** are fed by a transmitter **29** through a coaxial cable **30**. The outer conductor of cable **30** is connected to the metallic shell of the satellite **20**, and the inner conductor of cable **30** is connected to antenna elements **24** and **25**. The transmitter **29** feeds cable **30** at a point one quarter of a wavelength of the transmitter operating frequency from antenna element **25** and three quarters of a wavelength of this frequency from antenna element **24**. Antenna elements **24** and **25** each have a physical length equal to one quarter of a wavelength of the operating frequency of transmitter **29**.

As illustrated in FIG. 5c, four monopole antenna elements (**21**, **25**, **23**, and **26**) are insulatedly attached, in the same plane 90° apart, to the outer surface of satellite **20**. Monopole antenna elements **23** and **26** are fed by a transmitter **31** through a coaxial cable **32**. The outer conductor of cable **32** is connected to the metallic shell of satellite **20**, and the inner conductor of cable **32** is connected to antenna elements **23** and **26**. The transmitter **31** feeds cable **32** at a point one quarter of a wavelength of the transmitter operating frequency from antenna element **26**, and three quarters of a wavelength of this frequency from antenna element **23**. Antenna elements **23** and **26** each have a physical length equal to one quarter of a wavelength of the operating frequency of transmitter **31**.

In the operation of the embodiment of the invention shown in FIGS. 5a, 5b, and 5c, signals applied to cables **28**, **30** and **32** by transmitters **27**, **29** and **31** are respectively applied to antenna element pairs **21**, **22**; **24**, **25**; and **23**, **26**. The antenna elements of each pair are fed 180° out of phase by their respective transmitters. Transmitter **27**, at its operating frequency, feeds antenna element pair **21**, **22**, and antenna element pairs **24**, **25** and **23**, **26** are parasitic elements at that frequency. Transmitter **29**, at its operating frequency, feeds antenna element pair **24**, **25** and antenna element pairs **21**, **22** and **24**, **25** are parasitic elements at that frequency. Transmitter **31**, at its operating frequency, feeds antenna element pair **23**, **26**, and antenna element pairs **21**, **22** and **24**, **25** are parasitic elements at that frequency.

The parasitic actions of the three antenna element pairs are optimum when the three operating frequencies are fairly close to each other, preferably within 20%, due to the resonant characteristics of the antenna elements. However, if the three operating frequencies are more than 20% apart, there will still be some parasitic action. This multifrequency embodiment produces a more omnidirectional coverage than the single frequency embodiment of FIG. 3; in addition, it can radiate at three independent frequencies simultaneously. If necessary, tuned circuits can be used to keep each pair of fed antenna ele-

ments from feeding into the circuits associated with the other pairs of antenna elements. This multifrequency embodiment has an added advantage in satellite application where balanced weight is important—the circuit units feeding each pair of antenna elements can be spaced more uniformly within the satellite.

Obviously numerous modifications or variations of the present invention are possible in light of the above teachings. For example, a receiver can be substituted for any transmitter. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described herein.

What is claimed is:

1. An antenna system for use on an unoriented spherical metallic satellite comprising: four monopole antenna elements each having a physical length equal to one quarter of a wavelength of the operating frequency of the antenna system; means for insulatedly attaching the said four monopole antenna elements to the outer surface of the satellite in a common plane 90° apart; means for applying, at the operating frequency, signals to be radiated 180° out of phase to an adjacent two of said four monopole antenna elements; and a floating resistor means connected to the other two of said four monopole antenna elements to form an antenna element pair whereby the omnidirectional coverage of the antenna system is improved.

2. A dual frequency antenna system for use on an unoriented spherical metallic satellite comprising: four monopole antenna elements two of which have a physical length equal to one quarter of a wavelength of one of said dual frequencies and the other two of which have a physical length equal to one quarter of a wavelength of the other of said dual frequencies; means for insulatedly attaching said four monopole antenna elements to the outer surface of the satellite in a common plane 90° apart with the monopole antenna elements having equal lengths adjacent to each other; means for applying, at one of said dual frequencies, signals to be radiated 180° out of phase to the two monopole antenna elements whose lengths are equal to one quarter of a wavelength of said one of said dual frequencies; and means for applying, at the other of said dual frequencies, signals to be radiated 180° out of phase to the two monopole antenna elements whose lengths are equal to one quarter of a wavelength of said other of said dual frequencies whereby two monopole antenna elements are active and two are parasitic for each of said dual frequencies.

3. A multifrequency antenna system for use on an unoriented spherical metallic satellite comprising: six monopole antenna elements, two of which have a physical length equal to one quarter of a wavelength of a first frequency, two of which have a physical length equal to one quarter of a wavelength of a second frequency, and two of which have a physical length equal to one quarter of a wavelength of a third frequency; means for insulatedly attaching said six monopole antenna elements at points equally spaced around the outer surface of the satellite with the monopole antenna elements having equal lengths adjacent to each other; means for applying, at said first frequency, signals to be radiated 180° out of phase to the two monopole antenna elements whose lengths are equal to one quarter of a wavelength of said first frequency; means for applying, at said second frequency, signals to be radiated 180° out of phase to the two monopole antenna elements whose lengths are equal to one quarter of a wavelength of said second frequency; and means for applying, at said third frequency, signals to be radiated 180° to the two monopole antenna elements whose lengths are equal to one quarter of a wavelength of said third frequency whereby two monopole antenna elements are active and four are parasitic for each of said first, second, and third frequencies.

4. An antenna system for use on an unoriented satellite comprising: four monopole antenna elements equally spaced around and mounted in a common plane, on the outer surface of the satellite; means for applying signals to be radiated 180° out of phase to an adjacent two of the four monopole antenna elements; and means for loading the other two monopole antenna elements to form a parasitic antenna element pair whereby the omnidirectional coverage of the antenna system is improved.

5. An antenna system for use on an unoriented satellite comprising: four monopole antenna elements physically spaced 90° apart around the satellite in a common plane; and means for applying signals to be radiated 180° out of phase to an adjacent two of the four monopole antenna elements, whereby the other adjacent two monopole antenna elements form a parasitic antenna element pair which improves the omnidirectional coverage of the antenna system.

6. A multifrequency antenna system for use on an unoriented satellite comprising: six monopole antenna elements attached at different points to the outer surface of the satellite; means for applying separate different frequency signals to be radiated to each of three antenna element pairs formed by adjacent monopole antenna elements of the six monopole antenna elements whereby three different frequency signals are radiated simultaneously each signal being radiated by an active antenna element pair and by two parasitic antenna element pairs to improve the omnidirectional coverage of the antenna system.

7. An antenna system for radiating signals at three different frequencies simultaneously comprising: three pairs of monopole antenna elements formed by adjacent monopole antenna elements with the two antenna elements of each pair being approximately equal to one quarter of a wavelength of their operating frequency in length; means for applying different frequency signals to each pair of antenna elements and for applying the signals to the two monopole antenna elements of each pair 180° out of phase whereby each signal is radiated by an active antenna element pair and by two parasitic antenna element pairs to improve the omnidirectional coverage of the antenna system.

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